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Renewable energy in the Kujawsko-Pomorskie Voivodeship (Poland)

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ABSTRACT

In this article we presented the current state and prospects for development of renewable energy in the Kujawsko-Pomorskie Voivodeship, in which the greatest amount of renewable energy in Poland is obtained. In this area there are 96 wind power plants, 103 water power plants, 7 biogas power plants, 4 biofuel producing plants, 3 big energy willow (*Salix viminalis*) plantations as well as numerous biomass boilers (mostly using wood). In the near future it is planned to further develop renewable energy based on wind, water and biomass.

Contents

1. Introduction

Due to the negative impact of conventional energy on the environment as well as running out of fossil fuels, more and more importance is put on the development of renewable energy. According to the report by Global Wind Energy Council (GWEC) [1] and the report by The European Wind Energy Association EWEA 2009 [2], wind energy experiences the greatest increase in installed power compared to all other energy production technologies.

The biggest number of wind power plants was created in China – the number of 5910 from 2007 was doubled to 12,210 in 2008 [1]. A rapid growth in wind energy is taking place in Turkey – 147 plants in 2007 and 433 in 2008 as well as in Poland – 276 plants in 2007 and 472 in 2008. At the end of 2008 the combined power of wind installations in Europe was 64,949 MW, which is 15% more than in 2007 [1,2].

Water power plants worldwide produce about 16% of global electric energy, the most of which is produced by Brazil, Canada, China, the USA and Russia [3]. In Poland the most common are small water power plants (power below 5 MW) [4]. The power of water energy worldwide increases every year by 2% on average; the biggest increase by about 5% is in Asia (China) [5].

Asia is leading the biomass production (43%), whilst the most of bioethanol is produced in the USA and Brazil, and, in Europe, by Germany [6]. In Germany power production based on biogas is blossoming – in 2006 biogas power production increased by 56% [3].

Poland is a country where energy is obtained mostly from coal. Joining the EU imposed a duty on Poland to adjust emission parameters to those binding in all EU countries. In 2001 the Ministry of Environment created a special programme aimed at

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harmonisation of Polish and European standards on pollution emission and percentage of alternative (renewable) energy per total electric power production in the country. This programme was named "The Strategy for the Development of Renewable Energy Sources (OZE)" [7]. The strategic aim was to increase the percentage of renewable sources energy in the country fuel and energy balance to 7.5% in 2010 and to 14% in 2020 in the structure of primary energy carriers' usage.

In terms of energy management, ensuring ecological safety means that environmental effects of fuel resources exploitation need to be minimised. It needs to be ensured that renewable energy, in the amount relevant to the country's technological and economic potential, takes part in meeting growing energy needs of society and economy [7].

In this article we presented the results of sociometric research describing the current state and future prospects of renewable energy in Poland, using the example of Kujawsko-Pomorskie Voivodeship. For this reason the research was carried out using surveys: "The State of Wind Power Plants in the Kujawsko-Pomorskie Voivodeship," "The State of Water Power Plants in the Kujawsko-Pomorskie Voivodeship" and "Surveys for the Communes of Kujawsko-Pomorskie Voivodeship" as well as using the data obtained directly from renewable energy producers.

2. The description of the Kujawsko-Pomorskie Voivodeship

Established in 1998, the Kujawsko-Pomorskie Voivodeship (Fig. 1) covers the area of 17,972 km^2, which is 5.7% of Poland's area, and is inhabited by 2.1 million people, which is 5.4% of country's population [8,9]. The Kujawsko-Pomorskie Voivodeship is situated in the central part of the Polish Plain, in temperate warm climate zone – transitional between the oceanic climate of Western Europe and the continental one of Eastern Europe and Asia. The climate of the voivodeship is transitional between the cool and wet one of Northern Poland and the dry one of Central Poland. The coldest month is January whilst July is the warmest one. The average temperature oscillates within a year between +18.1 °C in July and −2.5 °C in January. The rainfall varies between 580 mm in the north-east and 450 mm in the south-west and is among the lowest in the country [8,9].

About 80% of the voivodeship area lies in the Vistula Basin. It is only the western and west-southern parts of voivodeship that belong to the Odra Basin. Forests and forestlands take up 408,471 ha of the Kujawsko-Pomorskie Voivodeship area. The forestation factor for 2006 is 23.1% and is below the Polish average (28.7%) and the European average (32%). In terms of spatial distribution, forests take the second place after arable land in the structure of land use in the voivodeship [8,9].



Fig. 1. The location of the Kujawsko-Pomorskie Voivodeship in Poland (black colour).

The emissions from heat and power stations and from production processes dominate the structure of total pollution emission in Poland and in the Kujawsko-Pomorskie Voivodeship [10]. It is only in case of nitrogen dioxide and carbon monoxide emissions that mobile sources are of higher importance whilst in case of dust and carbon dioxide local boiler plants and domestic fires participate greatly in emissions.

The harmful concentrations of air pollution are registered in central districts of big cities. This is due to transport pollution (formaldehyde, benzene, toluene), low emission as well as the influence of individual emitters. The concentration of transport pollution tends to increase slowly but steadily. The research into benzene pollution of air showed that acceptable concentration levels were exceeded in 96% of measuring stations. The investigations carried out the passive way indicated increased nitrogen dioxide concentration around main country roads as well as local ones of high traffic density. The results of monitoring research showed that energy production emission (including low emission from domestic fires) contributes greatly to the total air pollution emission in smaller towns [10].

3. The production of renewable energy in the Kujawsko-Pomorskie Voivodeship

The Kujawsko-Pomorskie Voivodeship is the leader in the production of alternative energy in Poland. In 2005 total energy obtained in our region from biogas power plants, biomass power plants, wind power plants, water power plants as well as coal and biomass power plants reached 31.36% of energy from produced in Poland. In the following years this value reached respectively: 27.65% (2006) and 25.79% (2007). By May 2008 the participation of Kujawsko-Pomorskie Voivodeship in the production of alternative energy in Poland was 35.46% [11].

3.1. Wind power

The analysis of wind energy zones in Poland (Fig. 2) shows that the Kujawsko-Pomorskie Voivodeship is situated in good and very good zones [12]. In addition, various research articles such as Risø National Laboratory show that wind conditions in the Kujawsko-Pomorskie Voivodeship are similar to those in Germany and are not much different from the conditions registered in Denmark and Holland [13].

In the Kujawsko-Pomorskie Voivodeship winds tend to blow mainly from the western direction (Fig. 3 represents the wind rose for Toruń) [14], their mean speed reaches 4–5 m/s [8], which is sufficient to install wind power plants [15,16]. The favourable climate conditions mean that in the future wind energy will be the strongest developing branch of alternative energy in the Kujawsko-Pomorskie Voivodeship.

Since 2002 between 11 and 20 new wind power plants are installed in the Kujawsko-Pomorskie Voivodeship every year. According to the data obtained from sociometric surveys there are 96 wind power plants operating in the Kujawsko-Pomorskie Voivodeship [17,18].

Fig. 4 shows the location of wind power plants and wind farms in the Kujawsko-Pomorskie Voivodeship. Wind energy has developed well in the south (Radziejów District) and in the centre of voivodeship. It is due to good wind conditions as well as interest among farmers [17,18].

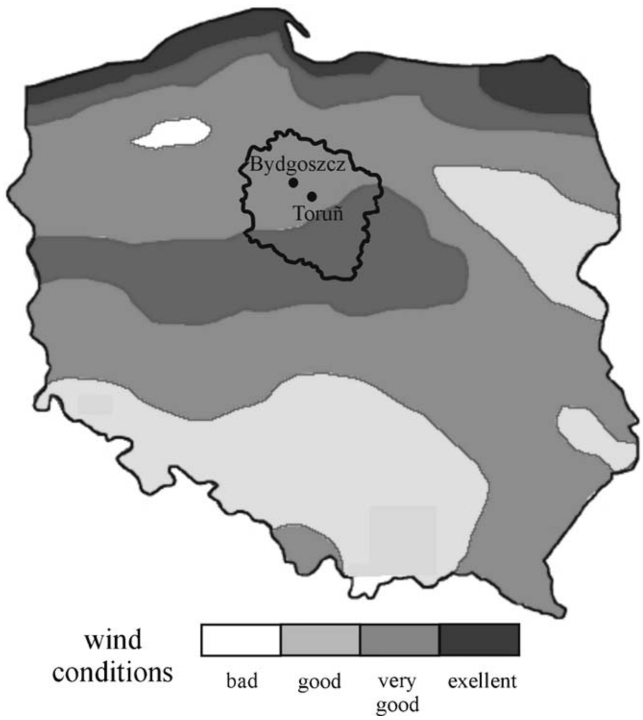


Fig. 2. Wind energy zones in Poland [13].

Basing on the conducted survey "The State of Wind Power Plants in the Kujawsko-Pomorskie Voivodeship", it could be concluded that [17] the investment process of power plant construction lasted between 4 and 36 months, the investment costs varied between 0.3 and 1.6 million PLN, which was mostly covered by credit. The main problems of investment realization are the high cost of investment, resistance of the local community, administration problems (too long waiting time for the construction permit, an excessive amount of required documentation, unclear law regulations), difficulties in getting connected to high power line as well as problems with obtaining the right equipment.

For example, energy production out of wind was started in 2003 in the Radziejów District [19] – this district has at the moment the highest number of wind power plants (58). According to the information provided by the District Office in Radziejów, there are more and more problems with obtaining the appropriate location for investment as well as with connecting power plants to the power network due to its high overloading. Despite these difficulties, the investors from the district area are still trying to implement projects of this kind. The total predicted power of wind power plant generators is to reach 2540 MW [19].

The survey research showed that 90% of participants are planning to extend their power plants in the near future. Among them 55% are planning to install 1 power plant, 36% 2 power plants and 9% 3 or more power plants. The highest number of wind power plants is planned to be erected in Inowrocław District (105), followed by Nakło District (51), Radziejów District (43), Lipno District (35) and Włocławek District (32) (Fig. 5) [18].

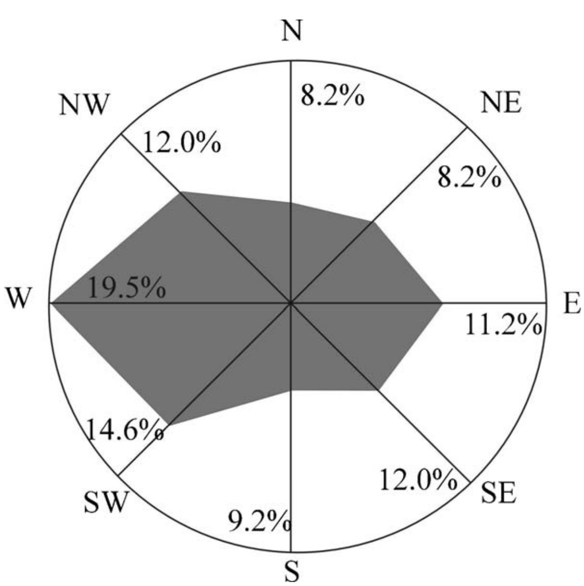


Fig. 3. Wind rose for Toruń [14].

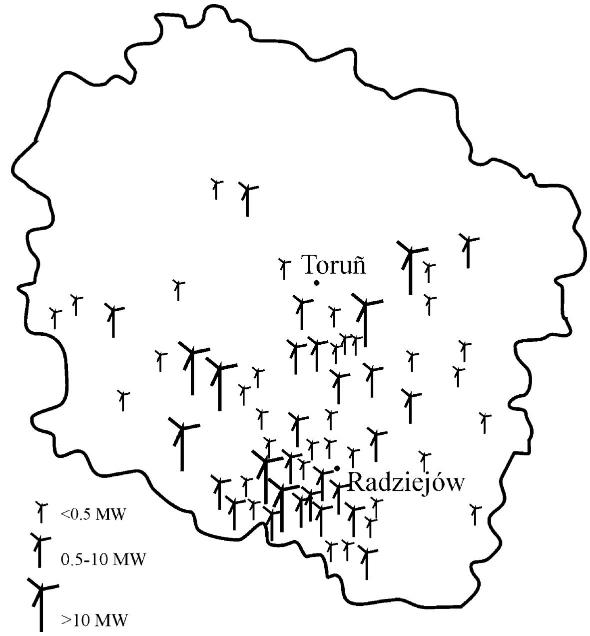


Fig. 4. Wind power plants and wind farms in the Kujawsko-Pomorskie Voivodeship.

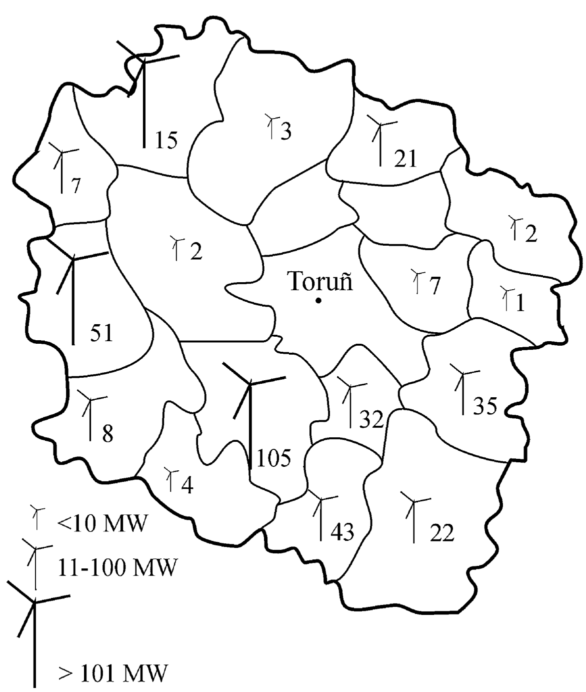


Fig. 5. Planned wind power plants and their total power in the districts of Kujawsko-Pomorskie Voivodeship.

3.2. Hydropower

In the Kujawsko-Pomorskie Voivodeship there are currently 103 water power plants operating (Fig. 6) [18,20,21], located mostly in the northern and eastern parts of voivodeship. It is related to numerous watercourses, dams and canals situated in this area [8]. The majority of power plants are small objects that favourably influence retention in a given area. The biggest power plant in the voivodeship is Power Plant Włocławek (stage of fall on the Vistula River). The stage of fall consists of the following parts: frontal earth dam, 10-bay weir closed by steel sheathed bolts, a power plant and navigation sluice of dimensions 12 m × 115 m, designed for the flow capacity of 6 million tons/year as well as a fish pass located in the dividing pillar between the weir and the power plant. In the power plant there operate 6 Kaplan turbines of installation power 160.2 MW [22].

In the survey "The state of water power plants in the Kujawsko-Pomorskie Voivodeship" [20], the participants say that the majority of discussed power plants are situated on rivers (70%), 20% are located on river dams, and the remaining ones use different watercourses. The time of investment realisation took between 3 and 72 months (years 2002–2008). The investment realization costs were contained within 0.04–6 million PLN. The power plants created recently are mostly financed using loans and credit (about 60%), however, the owner's capital is more considerable when compared to wind power plants. A vast majority of owners (93%) sell power to energy companies. The Vistula River is a hydrographical axis of the voivodeship, flowing 205.3 km through its area, of which 21.7 km is through the Włocławek Reservoir. Even though the voivodeship area is typical lowland, it is possible to successfully develop small power plants on numerous watercourses, improving water retention and at the same time preventing steppe formation [8,22].

About 60% of participants of the survey "The State of Water Power Plants in the Kujawsko-Pomorskie Voivodeship," are going to extend the already existing or install a new hydropower plant, with the money mainly sourced from loans and credit [20].

According to *The Kujawsko-Pomorskie Voivodeship Environmental Protection Programme* [23], so-called *Small Retention Programme* is to be realised in the area of voivodeship by 2015. This programme stipulates that new 528 investments are to be created on reservoirs and watercourses of our region. Taking into consideration the current location of small water power plants (mainly in the northern part of voivodeship) as well as a higher total of annual rainfall in the northern areas of our region, it can be expected that this area will continue to be used to implement such investments.

3.3. Biomass

In the Kujawsko-Pomorskie Voivodeship there are more and more places where energy plants are cultivated (mostly energy willow and topinambur). Fig. 7 shows the biggest plantations in the Kujawsko-Pomorskie Voivodeship [24]. In 2007 the areas of individual energy crops (ha) were: spring and winter rapeseed: 2419, corn: 51.4, winter triticale: 31.8, oats: 14.7, energy willow: 7.4, sugar beet: 2.1 [18]. It needs to be pointed out that virtually every household that burns coal to produce heat also uses biomass in a smaller or bigger amount (mostly wood).

In the Kujawsko-Pomorskie Voivodeship it is also the big companies that start to use the "green" energy. Thermal Power Plant in Świecie is an example [25]. In 2003 the company Polish Energy Partners S.A. built a modern circulating steam fluidised boiler CFB (*Circulating Fluidised Bed*) of capacity 234 t/h for "Saturn" power plant in Świecie. It is the biggest CFB boiler in Poland, enabling biomass combustion as well as supplementary hard coal combustion in any proportions. The most of biomass used for energy production consists of paper production and wood treatment waste. Additionally, the company buys sawdust and bark, mainly from local saw mills. In 2008 biomass provided 60% of all the fuels used in heat and power plant "Saturn" [18].

In the Kujawsko-Pomorskie Voivodeship there are a number of biogas plants using municipal waste and activated sludge from a sewage treatment plant. The biggest biogas plant is situated in the

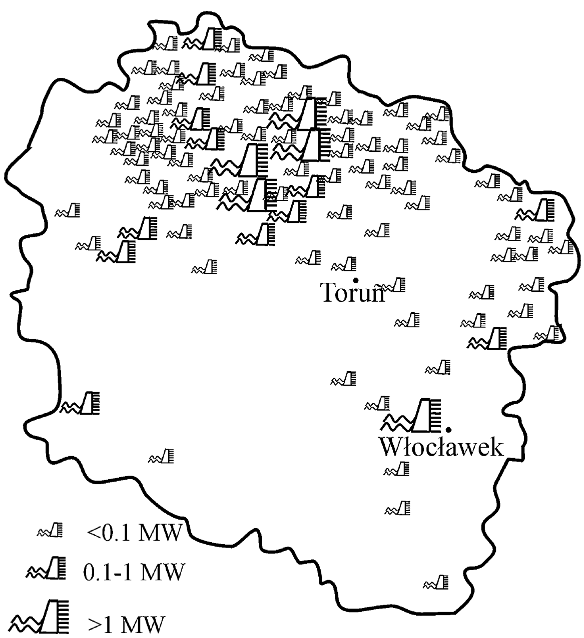


Fig. 6. Water power plants in the Kujawsko-Pomorskie Voivodeship.

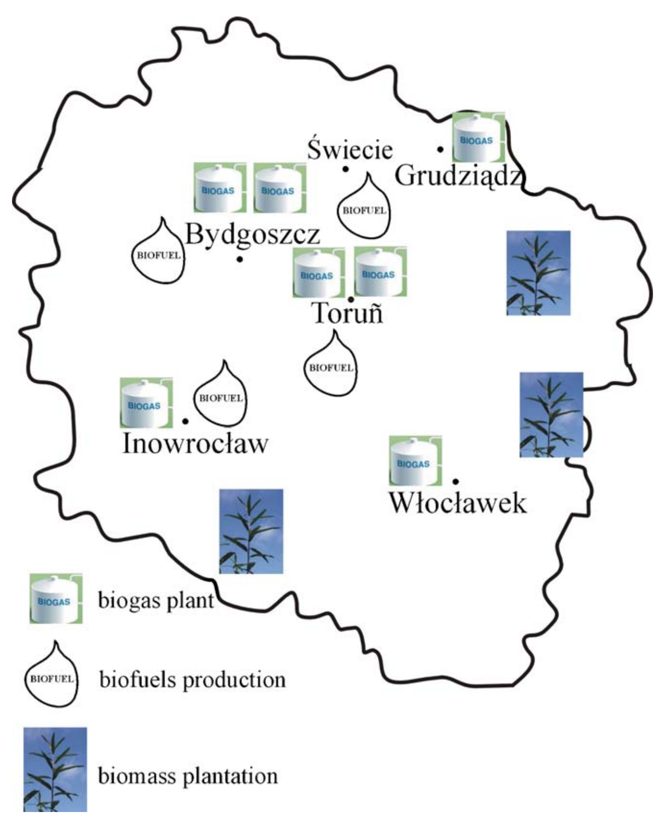


Fig. 7. Biomass energy in the Kujawsko-Pomorskie Voivodeship.

Table 1
The producers of liquid biofuels and biocomponents in the Kujawsko-Pomorskie Voivodeship [29].

No.	Name of producer	Kind and range of activity	Installation type	Annual efficiency (million dm^3)
1	BIOETANOL AEG Sp. z o.o.	Production and storage of bioethanol	Ethanol dehydration using molecular sieves	20
2	ALEKS – FRUIT Sp. z o.o.	Production and storage of esters	×	10
3	ATROPIN Sp. z o.o.	(a) Production, storage and marketing of methyl esters (b) Production, storage and marketing of pure vegetable oil	Rapeseed oil esterification Rapeseed pressing	25 5
4	BAUKUR Sp. J.	Production, storage and marketing of methyl esters	No-pressure method	3

(×) No data available.

north part of Toruń within the grounds of the Municipal Waste Disposal Site [26]. In December 1999 the work was completed and permit obtained to use the biogas plant in Toruń. Also, a company Biogaz Inwestor was created [27]. In 2001 the maximum technical and exploitation parameters were achieved. The area of 11 ha of the waste disposal site at Kociewska Street in Toruń was subject to gas exploitation. In this area 40 gas wells of 15 m depth were drilled and a network of suction leads was installed. In April 2002 further 3 ha of the waste disposal site were subject to gas exploitation as 12 more biogas wells were built and connected to the network.

The further stage of biogas installation extension consisted of building 17 biogas wells and suction gas network, which commenced work on 28th of August 2007. At present, 67 wells are exploited, from which about 300,000 m^3/month of waste site gas is obtained of average composition [26,27]:

- CH_4 (methane) – 55%,
- CO_2 (carbon dioxide) – 36%,
- O_2 (oxygen) – 1% and
- N_2 (nitrogen) – 8%.

The total value of energy produced throughout a year stays at the level of 11,000 kWh, with the highest values reached in 2004 and 2005 (12,327 kWh). In 1998–2006, 22.5 million m^3 of biogas was utilised, including 12 million m^3 methane, which corresponds to 22,897 Mg of hard coal. Combustion of such an amount of coal leads to the emission of 1004 Mg of CO_2, 357 Mg of SO_2, 29 Mg of NO_x and 502 Mg of dusts [26,27]. In Toruń biogas is also obtained in the Municipal Sewage Treatment Plant. Created during the fermentation of surplus sludge, biogas is combusted in two gas engines. Electricity generating sets have power of 2× 300 kWe. Biogas installation consists of a gas container of volume of 2700 m^3 and a torch to burn excess gas. Created during fermentation gas is then subjected to desulphurisation and dehydration in scrubbers [28]. In addition, there are 2 biogas plants in Bydgoszcz and one in the vicinity of respectively Grudziądz, Inowrocław and Włocławek (Fig. 7) [28].

In the register of producers of liquid biofuels and biocomponents, the data valid on 14th of May 2009 [29], four companies from the Kujawsko-Pomorskie Voivodeship are mentioned (Table 1). Further development of biofuel production in the voivodeship is possible due to the agricultural character of economy as well as a high number of distilleries.

In the near future the energy companies operating within the Kujawsko-Pomorskie Voivodeship plan to extend the power production based on biomass. The company-Grupa Energa started implementing a programme An Energy Safe Commune-Energy Biogas. In co-operation with the communes of central and northern Poland (including the Kujawsko-Pomorskie Voivodeship), the company wants to build a few hundred biogas plants. The first biogas plants are due in 2010 [30].

The Toruń energy company – Energetyka Cergia S.A. aims to gradually replace hard coal with biomass. It is estimated that initially at least 200,000 tons of biomass will come from energy plants cultivations. Energy plants cultivations would be continually developed so that the amount of biomass in combusted fuel would increase regularly. Due to the experiences in plant cultivation in Poland, it is assumed that plantations of such energy plants as energy willow and miscanthus will be developed [31].

Since January 2006 the Toruń company Biogaz Inwestor as well as the Section of Chemical Proecological Processes, Faculty of Chemistry of Nicolaus Copernicus University are the partners of the European project BIOGASMAX, the name of which is the acronym of BIOGAS AS TRANSPORT FUEL – MARKET EXPANSION TO YEAR 2020 – AIR QUALITY [27]. The project is planned for the years 2006–2009 and involves 28 partners from 8 European countries. The basic goal of BIOGASMAX project is to support the European community to become less dependent on traditional oil based fuels and to reduce the greenhouse gases' emission by acquiring knowledge about efficient production, distribution and use of biogas in a transport sector. In this case it is essential to investigate the possibilities of biogas production from various substrates and their mixtures, analysing the production process and quality of obtained solid and liquid products, which also need to be managed in an environmentally safe way [32]. One of the mentioned projects will be the construction of biogas plant in Toruń, the substrate for which is to be corn silage with the addition of other substrates (e.g. carrot pomace which is a by-product from a juice factory). Another possible substrate is post-distillation broth from an ethanol plant. This substrate seems to be more economic since its management is currently difficult for the distillery. The target efficiency of the plant is estimated at 1200 m^3/h of biogas of methane content of about 10 million m^3/year, which after purification provides about 700 m^3/h of biofuel, containing about 98% of methane. This amount would be sufficient to power 85 city buses CNG (at present there are 135 city vehicles), due to run in the area of Toruń. At the same time, the post-fermentation sediment (annually about 50,000 Mg) can be used as a fertiliser due to its high quality [26,32].

4. Conclusions

The Kujawsko-Pomorskie Voivodeship is the place where the highest amount of renewable energy in Poland is obtained. It contains 96 wind power plants, 103 water power plants, 7 biogas plants, 4 biofuel producing plants, 3 big plantations of energy willow and numerous biomass (mostly wood) boilers. In the near future it is planned that renewable energy based on wind, water and biomass will continue to develop.

According to "Environmental Protection 2007" [33], the area of fallow lands within arable land in the Kujawsko-Pomorskie Voivodeship is 20,000 ha, there are 4400 ha of degraded land and 43,100 of uncultivated land.

These areas could be used to a great extent for renewable energy production – either by energy plants cultivation or by constructing wind power plants. In case of degraded land it is possible to carry out soil reclamation using energy plants.

The prospective investors in the Kujawsko-Pomorskie Voivodeship, similarly to the rest of Poland, are put off by initially high investment capital expenditure of renewable energy sources technology and high costs of investment preparation in relation to running costs. Moreover, the lack of precisely defined economic and tax mechanisms in the Polish budget and financial politics as well as the lack of strategies, programmes and schedules for using means from ecological and quasi-budget funds deter investors and hamper a stable development of the renewable energy sector at the lowest costs. It is due to the lack of knowledge about the location of resources, the procedures to follow when locating investment, access to technology and funding as well as unfamiliarity with renewable energy sources throughout various administration stages.

The installations using the renewable energy in the Kujawsko-Pomorskie Voivodeship are typically local and do not require a centralised technical infrastructure. Being small and scattered technologies, they are naturally linked to politics, strategy and development plans of the European Union and of the local region.

Acknowledgements

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